NOTES ON ARTILLERY:

FROM

ROBINS, HUTTON, CHESNEY, MORDECAI, DAHLGREEN, JACOB, GREENER, GIBBON AND BENTON.

BY

W. LEROY BROUN, M. A.,
Lieutenant Artillery, Virginia Volunteers.

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CHAS. H. WYNNE, PRINTER.

PREFACE.

The writer, having had access to several interesting works on the subject of artillery that are now very difficult to obtain, has concluded to publish these "Notes," hurriedly written, as they have been, in a few spare days. He does so with the hope that they may interest and instruct his fellow-comrades in arms, especially those who have lately entered this arm of the service, and may in some remote degree aid the great cause so dear to his heart.

He has had access to and used the information derived from the following works:

Artillerist's Manual, by Lieut. Gibbon, U. S. A.
Ordnance and Gunnery, by Capt. J. G. Benton, U. S. M. A.
Shells and Shell Guns, by Com. J. A. Dahlgreen, U. S. N.
Rifles and Rifle Practice, by C. M. Wilcox, U. S. A.
Notes on Sea Coast Defence, by Maj. J. G. Barnard, U. S. A.
The Science of Gunnery, by William Greener, of London.
Observations on Fire Arms, by Col. Chesney, Royal Artillery.
Military Commission to Europe, by Maj. Mordecai, U. S. A.
Treatise on Fire Arms, by Lieut. Simons, Bengal Artillery.
Rifle Practice, by Col. Jacob, Bombay Artillery.

He has also made use of information derived from the writings of Robins and Hutton.

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NOTES ON ARTILLERY.

I.

ANCIENT AND MODERN ARMS.

The common sling, no doubt, constituted the first kind of Artillery, which was followed by the bow and arrow, and this latter weapon was improved in succeeding ages by the ballista and catapulta, &c. The ballista of the ancients hurled stones from 2 to 300 pounds weight, or even, it is said, 500 pounds, about 100 yards, and the catapulta projected arrows and iron bolts twice that distance. These machines were in use more than a thousand years before the Christian era, when Uzziah had engines in Jerusalem "invented by cunning men, to be upon the towers and upon the bulwarks, to shoot arrows and great stones withal." (2 Chron. xxvi. 15.)

Gunpowder became generally known in Europe in 1320; and about this time it was first used in Europe to project rounded stones from short conical guns, made in the shape of an apothecary's mortar. These were succeeded by *Perrieres*, made longer and cylindrical of bars of iron bound together by hoops, with a chamber for the powder. The introduction

of the cast iron, instead of the stone projectiles, caused the rejection of the *Perrieres* for the *Culverins*, a gun somewhat like that used at present, of cast metal, only much longer bore, and generally ornamented in the exterior with various devices. There is one now at Dover, England, 25 feet long, which throws a projectile of 18 pounds, called "Queen Anne's Pocket Piece."

While it is generally admitted that the use of artillery became common in Europe in the fourteenth century, we should not fail to mention, that the Chinese claim to have been familiar with gunpowder and fire arms long before the Christian era, and it is said that the Moors used artillery against Saragossa in 1118, and that a Culverin of 4 pounds calibre was made by them in 1132. In a catalogue prepared in 1381, of ordnance at Bologna, there is mention made of a copper gun which carried a ball of 361 pounds' weight, and of three iron ones which carried square projectiles. In the repository at Woolwich, there is a gun marked, "Henry VI. 1426," with a movable breech; thus showing that breech-loading cannon are of the very earliest construction. Divers calibres were early made. Charles VIII. of France restricted his artillery to six different calibres; and, when invading Italy (1494), carried in his train 1,000 *hacquebuttes*, or hand guns, weighing about 50 pounds each. These were fixed with a rest or stand. Shortly afterwards, a lighter gun was made, called an *arquebuse*. In 1524, the Spaniards gained a victory over the French by the employment of 2,000 arquebusiers and 800 musketeers, "who now appeared for the first time discharging bullets of two ounces weight." We thus see that cannon had been in use two hundred years before the introduction of the musket.

All the various systems of calibres that were first intro-

duced in Europe were finally reduced to the French or German system, or to a combination of them. The French system consisted of calibres of 32, 16, 8 and 4 pounds. The German consisted of 48, 24, 12, 6, 3 and 1½ pounds.

A system of uniformity in the construction of guns was only introduced in France, in 1732, by Valiere, who caused a prescribed standard to be adopted. But, in 1765, Gribeauval effected the most important changes in artillery. He diminished the charge of powder from one-half to one-third the weight of the ball, and thereby made the gun much lighter; he disposed the horses in double file, having been previously arranged in single; he introduced iron axle-trees, cartridges instead of loose powder, elevating screws and tangent scales, and compelled all the arsenals to make the work according to fixed dimensions. Afterwards, he reduced all field carriages to two, making the wheels of the limber and of the carriage the same.

In 1850, the Emperor Louis Napoleon proposed and caused to be adopted in the French service only one calibre for field service a 12 pounder howitzer-gun, to be used with solid shot, to supply the place of the 8 and 12 pounder guns and of the 24 and 32 pounder howitzers. All the field batteries in the French service in the Crimean war consisted of these Napoleon guns, as they were called, each drawn by eight horses. In 1856, it was proposed to retain in service in the old United States only one calibre for field service, very similar to the new Napoleonic gun. The piece was to be brass, of 12 pounder calibre, 16 calibres long, weight 1,200 pounds; charge of powder 2½ pounds, same as in the old iron 12 pounder. The weight of this gun and carriage would be only 500 pounds more than the 6 pounder field piece with its carriage. To give great mobility to a portion of the battery, it

was proposed to retain in the service the light 12 pounder howitzer.

We thus see how gradual the improvements in artillery have been. It was many years before field artillery was separated from siege and garrison; and, even in 1830, a gun of 24 pounder calibre was the heaviest mounted on the sea-coast batteries of the United States, where now we find 10 inch columbiads, casting a ball of 130 pounds weight, with a charge of 16 pounds powder.

II.

GUNPOWDER.

The Chinese claim to have been familiar with gunpowder long anterior to the Christian era. We know not how much credit to give to their historic records, as they also claim to have recorded astronomical observations of phenomena that occurred thousands of years prior to the period assigned for the creation of the earth in the Mosaic cosmogony. By some it is supposed that the use of gunpowder was introduced into Europe by the Saracens. Roger Bacon, in his Treatise de Nullitate Magiæ, Oxford, 1216, gives the component parts of gunpowder; but it only became generally known throughout Europe in 1320, through the exertions of Bartholdus Schwartz.

Gunpowder is composed of nitrate of potassa, charcoal and sulphur, combined in proportions slightly varying in different countries, intimately mixed and granulated. The following table gives the proportions required by the atomic theory and those used by different nations:

TABLE OF COMPOSITION OF DIFFERENT GUNPOWDERS.

	Nitre.	Charcoal.	Sulphur.
Atomic theory would require	74.64	13 57	11.85
United States Military,	76	14	10
United States blasting and mining,	62	18	20
English,	75	15	10
French national,	75	12.5	12.5
French sporting,	78	12	10
Prussia,	75	13.5	11.5
Russia,	73.78	13.59	12.63
Austria,	72	17	16
Spain,	76.47	10.87	12.75
Sweden,	76	15	9
Chinese,	75	14.4	9.9

The explosive power of gunpowder is due to the rapid conversion of the solid constituents into heated gases. Carbonic oxide, carbonic acid, sulphurous acid and nitrogen are immediately set free, leaving a residuum of sulphuret of potassium. It is calculated that, without a change of temperature, the gases developed would occupy a space nearly one thousand times greater than powder in the solid form. But at the instant of change from solid to a gaseous condition, we know great heat is developed thereby, causing the gases to occupy a much larger volume, and increasing vastly the explosive power of fixed gunpowder. This "explosive power" is differently estimated by different experimenters, depending on the heat which they assume to be generated at the time of explosion.

Robins, who neglected entirely to consider the heat generated, estimated the explosive force of gunpowder at 1,000 atmospheres; Hutton estimated the force at 2,050 atmospheres; Dr. Gregory at 2,250; Gay Lussac at 2,137; and

Piobert estimated the force at as much as 7,500 atmospheres. The great difference due to these estimates is due to the fact, that it is impossible to estimate accurately the amount of heat generated at the instant of explosion.

The solid matter of powder is not *instantaneously* converted into gases. It requires an interval of time, no matter how short, to produce entire combustion, and the time required for the same weight of powder depends on the size of the grain. The larger the grain, the longer is the time occupied in combustion. Hence, in rifles and sporting guns very fine grain powder is used; while for guns of heavy calibre large grain powder is required. Were the powder in a 12 pounder gun *instantaneously* converted into gas, it would necessarily burst the gun. Time is required to overcome the *inertia of rest* of the ball. And as inertia is proportioned to the mass, the time required for the combustion of powder to safely project a ball from any gun is proportioned to the weight of the ball; hence, the larger the ball, the larger the grain of powder that is used.

It is said, that in the large Federal gun which projects a ball of 400 pounds, the grains of the powder used are larger than chestnuts.

The conversion of a portion of the charge produces sufficient force to impart motion to the ball, and its velocity continues to increase until all of the charge has been converted into a propellant gas. By increasing the length of the bore too much, friction of the ball against the bore is increased, and its initial velocity thereby diminished. By increasing the charge of powder, a portion of it is expelled from the gun before it is converted into gas, and thereby the velocity of the ball diminished by adding the weight of the unconsumed powder to the weight of the ball to the projectile.

From many careful experiments, Dr. Hutton by induction inferred the following laws:

1. The velocity varies as the square root of the charge.

2. The velocity of the projectile increases to a certain increase of charge; beyond that, it diminishes.

3. The velocity of the ball increases in a somewhat less ratio than the square roots of the lengths of the bore, and somewhat greater than the cube roots.

4. The range increases nearly as the square root of the velocity; hence, the range is nearly as the fifth root of the length.

Hence we see, by increasing the length, a very slight increase of range is obtained.

For field service, one-fifth of the weight of the projectile is used for a charge for solid shot, spherical case and shell from guns; for canister, one sixth of its weight; and for shell and case shot from howitzers, one-twelfth.

The French at one time used chlorate of potash in the manufacture of gunpowder; but it was soon abandoned, owing to its instantaneous explosion, as no piece of ordnance could resist its effects.

In field service, the cartridges should be well packed in their chests, with cotton or tow, to prevent their rubbing or jolting against the sides of the chest, as thereby, in their transportation, some of the grains of each charge would be liable to be ground to dust, and its efficiency much diminished. They should not be packed so tight as to interfere with a hasty removal from the chest should occasion require. The friction primers should be carefully packed in a small paper or tin box with cotton, and tied so as not to come loose in traveling, and placed in the tray separate from the powder. Of course, a dozen or so should be kept in the tube pouch

ready for immediate use. No broken cartridge or loose powder should be permitted in the chest, as it is an established fact that powder can be made to explode by the impact of a hard substance, and a few grains being between two balls brought powerfully together by a sudden jar might produce a serious explosion.

The ammunition chests should be opened and the cartridges carefully aired and sunned on every dry day succeeding damp weather.

III.

THE SMOOTH BORE AND THE HOWITZER—THE CAUSE OF THEIR DEVIATIONS.

Military writers assert that explosive hollow projectiles were used from 1521 to 1580, but it is doubted if the modern bomb was understood at that period. The present howitzer is an invention of the Dutch artillerists, and derives its name from the German *Haubitz.* The distinctive characteristic of the howitzer is that it has a chamber for the reception of the cartridge. The object of the chamber is to hold the small cartridge in position, that the whole explosive force may be exerted against the centre of the ball. Without it the small cartridge in the large bore would be displaced. It is also much shorter than other cannon of the same calibre, and being used with charges of only one-twelfth the weight of the solid ball, it is made much lighter, not requiring a great thickness of metal to resist the effects of explosion.

From the gun we fire solid shot, spherical case, shell or canister; but from the howitzer it is not usual to fire solid shot, as with the small charge of powder used, on account of limited amount of metal at the breech, but little initial velocity would be given the ball. The metal required to cast a 12 pounder gun put in the form of a howitzer, enables us to project a 24 pound shell. As shells are effective by their explosion and not by their velocity, it is not required that they should have an initial velocity as great as that given to solid shot.

In the United States the proportions between the weight of

the ball and the gun are, in the 12 pounder, 299 to 1; in the 42 pounder, 201 to 1; in the 10 and 12 inch columbiads, 137 to 1. In brass guns the proportion is 147 to 1.

Senderos places the tenacity or cohesive force of wrought iron at 4234 atmospheres, of bronze at 3872, and of cast iron at 1358 atmospheres; while Navier places the cohesive force of wrought iron at $4164\frac{1}{2}$ atmospheres, of bronze at 2475, and cast iron at 1307.

We thus see that wrought iron is the strongest material for guns, bronze next, and cast iron the weakest. From the difficulty of constructing wrought iron guns that material has not yet been successfully used. Bronze guns, composed of ten parts tin to one hundred of copper, are made much lighter than iron ones, on account of their greater tenacity, and hence that material is used for field pieces when it can be obtained. This is the only advantage that bronze guns have over iron ones, that of being lighter; while for long use and rapid firing, iron guns are superior to bronze, as we shall presently see.

The difference between the diameter of the ball and the bore of the gun, called *windage*, varies from nine-hundredths to sixteen-hundredths of an inch. On account of this, when the ball rests in the bore in front of the charge, there is a space in the upper part of the bore above the ball equal to the windage. When the charge is fired the propellant gas escapes largely by this unoccupied space above the ball, and wedges it down against the bottom of the bore with great power, causing it to form an indentation called a *bed*. When the gas acting behind the ball moves it forward, it does not move in the direction of the axis of the piece, but, on account of the obstacle of its bed, it rises upward and strikes the upper part of the bore, producing a burr, called a *lodgment;* and again is thrown down, producing another *lodgment,* forming thus two or

three *ricochets* in the bore before it issues from the muzzle. A bronze gun, being softer than the cast iron projectile, would, by repeated firing, have permanent *lodgments* made in its bore, which would seriously interfere with its accuracy of fire, and in time destroy the utility of the gun. When a gun is thus injured, its usefulness is in a manner restored by lengthening the *sabot*, causing the ball to assume a new *bed*. A bronze gun will not bear rapid firing, since when the metal becomes much heated, it is soft and the gun is apt to droop at the muzzle.

Cast iron guns are not injured by lodgments on account of their hardness, nor are they seriously affected by rapid firing. At the siege of Badajos the firing continued for 104 hours, and the number of rounds that each gun fired averaged 1,249. At the siege of Sebastian each gun averaged 350 rounds in 15½ hours. "The guns were of iron, and none were rendered unserviceable, though three times the number of brass guns would not have been equal to such long and rapid firing."

Experiments have shown that the power of a gun to resist explosion increases with the length of time that it is allowed to remain after cast before it is used. While guns cast but a few days have burst on a few fires, those cast for thirty years have resisted the shock of more than 2,000 rounds.

These deviations, which no accuracy of aim can wholly overcome, are due to two causes: (1) windage or difference between the diameter of the ball and the bore of the gun; and, (2) the *excentricity* of the centre of gravity of the ball or shell. These causes do not act separately, but the deviation is genarally the resultant of the two. Numerous experiments were made in France, as recorded in the Encyclopœdia Britannica, to observe the deviation of the projectile from the axis of the bore, by placing a screen 30 yards in front of the muzzle.

The result of the experiments demonstrated that the devi-

ation arising from the two causes, though not always, is, generally, an elevation. The average deviation amounted to $3\frac{1}{2}$ minutes in guns, and to $10\frac{1}{2}$ minutes in howitzers—one-fourth of the shot from the guns having an elevation of more than $8\frac{1}{2}$ minutes, and a depression below the axis of $1\frac{1}{2}$ minutes. In howitzers one-fourth had an elevation of more than $15\frac{1}{2}$ minutes, and one-fourth $5\frac{1}{2}$ minutes above the axis; the remaining shots passing within these limits. In a horizontal direction half of the shots deviated from the axis more than $4\frac{1}{2}$ minutes to the right or left.

The author of the article "Artillery," in the new American Encyclopœdia, says the effective range of field guns is not over 1,500 yards, at which distance one shot out of six or eight might be expected to hit the mark. The decisive ranges in which alone cannon can contribute to the issue of a battle are for round shot and shell, between 600 and 1,100 yards, and at these ranges the probability of striking the object is not very great. It is reckoned, that at 700 yards, about 50 per cent.; at 900 yards, about 35 per cent; and at 1,100 yards, about 25 per cent., out of the shots fired from a 6 pounder will hit a target representing the front of a battalion in column of attack, (34 yards long by 2 yards high).

In 1850 experiments in France with 8 and 12 pounders gave the following results against a target, 30 metres by 3 metres, representing a troop of cavalry:

Distance in metres,	500	600	700	800	900
Per cent. of 12 pounder hits,	64	54	43	37	32
Per cent. of 8 pounder hits,	67	44	40	28	28

This table shows the superiority of a 12 pounder over a 6 pounder for all distances over 550 yards.

From these experiments we would infer, that even if the centre of gravity of the projectile coincided perfectly with the centre of magnitude, still there would be considerable deviation, depending upon the angle which the projectile would make with the axis of the piece. But the main cause of the deviation is due to the excentricity of the projectile, which is measured by the distance between the centre of magnitude and the centre of gravity. Owing to the nature of the material of which projectiles are made, it is almost impossible to avoid excentricity; consequently, if we suppose the resultant of the propellant gas to act on the centre of form, and not on the centre of gravity, by a simple principle of mechanics it follows, that the ball will have both rotary and progressive motion, and the rotation will be around the centre of gravity. This rotation may be further modified by friction against the interior of the bore. Hence we may safely assert, that every round projectile fired from a smooth bore gun rotates around some axis. If this axis of rotation is not coincident with the line of fire, the projectile will be deviated from its straight course by the inequality of the resistance of the air on the sides of the revolving projectile. Suppose the axis of rotation of the ball is perpendicular to the line of fire, and the ball revolves from right to left, it is obvious that the resistance of the air on the right hemisphere of the ball is due to the velocity of progression added to that of rotation, while the resistance experienced by the left half is due to the velocity of progression diminished by that of rotation. Hence, under the circumstances, the right half would have a greater resistance acting upon it than the left. The resultant of this excess of resistance would tend constantly to *push* the ball to the left,

and thereby cause deviation from the line of sight in that direction.

In 1737 Mr. Robins, in his numerous experiments, observed these irregular deviations, and assigned these deflections "to the oblique action of the resisting medium on the surface of the ball, arising from its rotary movement."

In 1771 Robins' conclusions received a remarkable verification. A screen was placed 32 feet from the muzzle, and a ball which pierced the screen five-sixths of an inch to the right of the prolongation of the axis, at a range of 3,765 yards, deviated 230 yards *to the left*, and another which pierced the screen one inch to the left, at a range of 4,072 yards, deviated 230 yards *to the right*. These anomalies can be explained only by the rotary movement. As late as 1838 the subject of the excentricity of the deviations caused thereby was not generally understood, as is admitted by General Paixhans. This ignorance of an important subject, which had been explained one hundred years before, is by no means complimentary to artillerists.

We take the liberty of quoting upon this interesting subject from *Dahlgreen's Shells and Shell Guns:*

"The doctrine," he says, "commonly received and confirmed by experiment, in relation to excentricity and its consequences upon the trajectory of cannon balls, may be briefly summed thus: When the centre of gravity does not coincide with the centre of the sphere, a revolving motion is created around the centre of gravity, the direction of which depends on the position that the centre of gravity has to the centre of the sphere. This rotation during the flight of the projectile occasions a greater resistance on one side of the hemisphere, which is in front, than on the other; because on the former the progressive and rotatory motions concur, and on the other

they are in opposition. Hence, the projectile is made to incline from its direct course by the greater pressure which it sustains on one side; and the aberration thus produced will be in the prolongation of the plane passing through the axis of the bore and centre of gravity, and will occur on the same side of the trajectory as the centre of gravity occupies with respect to the axis of the bore.

"So that if the centre of gravity be in the vertical plane, the deflection from the normal trajectory will be vertical and upwards, or downwards, accordingly as the centre of gravity is in the upper or lower hemisphere. If above, the range will be increased; if below, decreased; by the very conditions of the case, and without lateral deviation.

"If the centre of gravity lie in the horizontal plane, the deflection will be entirely lateral and right or left as the centre of gravity may lie. If the centre of gravity occupy some position between the vertical and horizontal planes, as it commonly does, then the aberration will be partly vertical and partly lateral. It does not appear that the location of the centre of gravity in the anterior or posterior hemisphere, materially effects its operation; except that there is a slight increase of range where the centre of gravity is in the posterior hemisphere and in the axis of the bore."

Dahlgreen found, that by placing this centre of gravity of an excentric ball 90° up, the range was increased nearly 200 yards.

We will conclude the notes on this subject by mentioning some facts in regard to the ordnance of the siege of Sevastopol, taken from the report of Major Mordecai, of the Ordnance Department.

At the siege of Savastopol no cannon of extraordinary calibre or range, no breech-loading guns, no rifled cannon,

(except the Lancaster gun,) were put to the test of actual service. Before the *impromptu* fortifications of Sevastopol the allies placed in battery, at various times during the siege, more than 2,000 pieces of heavy ordnance, besides the hundreds of field pieces with which the troops were armed. The first siege train with which the French army presented itself before the place consisted of sixty pieces of the calibres usually employed in such operations, 16 and 24 pounder guns, 8 inch howitzers, and 8 and 10 inch mortars. These being soon found insufficient, were followed by other trains, amounting to 250 pieces. Many guns of heavier calibre were drawn from the fleet; but the armament which, at last, appears to have been most efficient in rendering the works untenable was a train of mortars, of which the French alone had 120 thirteen inch, the same number of ten inch, and about 100 eight inch. Add to these the English siege train of more than 900 pieces, consisting chiefly of 68 pounder and 32 pounder guns; 13 inch, 10 inch and 8 inch mortars; a considerable quantity of which were in battery at the close of the siege, and some idea may be formed of the storm of shot and shell which was poured upon the works during the bombardment of three days preceding the last assault.

"The appearance of the ground within the Malakoff and Redan bastions, after the retreat of the Russians, showed the impossibility of serving the guns of the palace during the bombardment. *It was scarcely possible to plant a foot on a spot on the terreplain of those works which was not marked by a cannon ball, or by the explosion of a shell, and the defenders could only remain there under cover of their bomb-proof shelters, which, although mostly constructed rudely of timber fascines and earth, seemed to have generally resisted the fire of the besiegers.*"

How very culpable have been those who have had charge of the construction of our fortifications! At Sevastopol, while under a fire and during the operation of the siege, the Russian engineer had "bomb-proof shelters of timber fascines and earth" constructed in the fortifications, which afforded a safe protection against a storm of shot and shell from 2,000 cannon during three days. While our engineers with months before them, and no enemy in sight, have been content to build *open pens*, which have surrendered after a brief struggle of a few hours. Let our generals in command see to it that our engineers have work done with no enemy to molest, at least as well as Totleben had constructed under the galling fire of the allies.

"The number of pieces of ordnance burst at Sevastopol was small in proportion to the whole number used. But it was stated, that about two-thirds of the ordnance used in the siege was considered unserviceable at its termination. Many of the guns had been rebouched; some of them two or three times; some bouchings of wrought iron were tried, but did not last long. The French siege trains were supplied with 1,500 to 2,000 rounds a piece; their batteries fired during the siege about 1,250,000 rounds of all kinds, and at the close there remained from 800 to 900 rounds of ammunition for each piece. The field batteries were supplied with 1,000 rounds for each piece."

Of all the guns used by the British only twelve burst. Three of these were Lancaster guns. In the report it is stated, that the 32 pounder guns fired on an average 1,500 rounds each.

Captain Kennedy, of the Royal Navy, says in his report: "The 68 pounders landed from the 'Terrible' were constantly in use, and I should say the least number of rounds

fired from any one of them was 3,000; some of them went up tc 4,000. They were fired with the 16 pounder charge, and frequently very rapidly."

The allies found in Sevastopol about 4,000 pieces of ordnance of all kinds; but the number of unserviceable pieces was *twice* the number in battery! Showing that the guns had been several times renewed. The Russian gunners were protected from sharp-shooters with the rifle by a mantlet, made of rope, to cover the embrasures.

A field-cannon ball will disable seven or eight men at a distance of 900 yards. It is said, that at the battle of Zorndorff, a single ball disabled forty-two men.

IV.

THE RIFLE CANNON—"DRIFT" OF THE BALL, AND ITS CAUSE.

It is stated that rifles have been in use since 1600. The principle of the rifle was clearly stated by Robins in 1737, viz: that as the deviation of the ball was caused by the *unequal* pressure of the air, produced by its revolution, this cause of deviation would be wholly destroyed by causing the ball to revolve around an axis coincident with the line of flight. The motion of rotation being at right angles to that of progression in no measure influences the resistance of the air. The ball is caused to revolve on this axis by "rifling" the bore, or cutting in it the threads of a female screw. The spherical ball was used with the rifle for many years, and this with the difficulty of loading, (the ball necessarily having to fit tight to take the threads,) prevented its adoption by troops in the field.

In 1829, Delvigne proposed to remove the difficulty of loading, by flattening a smaller ball on the edge of the chamber with a blow from the ramrod. Thouvenin afterwards proposed to use a small stem projecting from the breech plug into the bore, around which the ball was to be flattened by the rammer. Delvigne afterwards made the base of the ball flat; hence the conical or elongated ball.

Minie afterwards made the stem of Thouvenin in the form of a cone and fixed it in the ball, instead of the breech of the gun. This *culot*, by the propellant gas, (having less inertia) was thrown forward into the ball and expanded it to fill the bore. Afterwards it was discovered that the gas acting in the hollow cavity of the ball expanded it without the *culot* of iron. Hence we have the present "cylindro-conoidal ball."

W. Greener, of London, claims priority in the discovery of what is now called the "Minie ball."

About thirty years ago Cavalli S. Wahrendoff constructed breech loading rifle cannon, which eventually failed. Later, Lancaster introduced his rifle cannon of elliptical bore. It was like a smooth bore with its section an ellipse instead of a circle; having the major axis of the ellipse at the muzzle at right angles to the major axis at the breech.

Great results were anticipated of the Lancaster guns. They were tried at the siege of Sevastopol, and utterly failed to realize the expectations previously entertained. Several of them burst on account of the wedging of the shot in the bore, when the elliptical shot were abandoned and they were fired with spherical.

The principle of the expansion of the Minie ball was, immediately after its application to small arms, applied to rifle cannon. For a while there seemed a difficulty in attaching the hollow cup of soft metal at the base to the metal of the ball. This difficulty is now overcome, and the elongated ball is fired from rifle cannon of the largest bore. It has been found by fastening an inverted copper saucer at the base of the ball the windage is destroyed and the rotary motion given.

In the examination of the smooth bore, we found there were two principal causes of deviation in the ball, windage and the excentricity of the ball causing a revolution around some other

axis than that coincident with the normal trajectory. Both of these causes of deviation are entirely eliminated in the rifle cannon.

By the action of the gas on the soft metal at the base of the ball, it is expanded to fill up entirely the bore, and thereby cuts off all escape of a gaseous fluid. Hence the ball is projected with very great velocity, as all the propellant gas acts on it, and, moreover, its elasticity is much increased by thus confining it and allowing none to escape. The soft metal is thus pressed into the grooves, and as the ball moves forward it acquires a rotatory motion around an axis coincident with the axis of the bore. Hence the deviations to which the smooth bore is liable are entirely obviated in the rifle cannon, inasmuch as the expansion of the cup cuts off the escape of gas, and thereby prevents *lodgments* in the bore. The ball is made cylindro-conoidal, having thereby nearly twice the weight of a sphere of same calibre, and meets with much less resistance from the air. Considerably less powder is required to give a larger ball much greater range, with far greater accuracy, than can be done with a smooth bore.

While it is true that a ball from a rifle cannon is not liable to the enormous and irregular deviations of a smooth bore, yet it is found by practice to be subject to another deviation peculiar to itself. It is found that the ball will not continue to move in a vertical plane, but will depart from it towards the *right*, if the ball is revolving from left to right, or in the direction of the hands of a watch held before you. If the revolution of the ball is in the contrary direction, the departure will be towards the *left*. This deviation of the rifle ball is technically called the "*drift*" of the ball, and it is said the ball "drifts" in the direction in which it revolves. The "drift" only takes place with the elongated ball, and the amount of deviation seems to

depend on the range. The French rifle guns used in the Italian war were provided with a graduated lateral slide, by means of which the effect of this deviation was corrected. If the drift was towards the right, it became necessary to point the rifle towards the left of the object, which was done by sighting at the object over one of the graduations to the left of the vertical tangent right.

Sufficient number of experiments have not yet been made with our guns to determine the amount of deviation corresponding to each range, and without these experiments we do not know how to graduate this lateral sight.

The Armstrong gun is a breech loading rifle cannon of small calibre, with a bore made of twisted steel. It is said to have remarkable range and accuracy; that it may confidently be relied on placing shot after shot in a target 6 feet square at a distance of 3,000 yards. The "drift" of the gun is always towards the right, in the direction of its revolution. Colonel Jacob, in his "Rifle Practice, London, 1858," denies that the deviation of the ball is always towards the right, and that it is generally so, he attributes to the fact that the rifle is fired from the right shoulder. He argues that the breech of the rifle resting against the right shoulder, by the force of recoil, does not tend to move backwards in the prolongation of its axis, but tends to revolve around the centre of gravity of the mass of the body and rifle, which throws the muzzle of the rifle slightly towards the right before the ball is clear of the bore, thus causing the generally observed deviation. He further adds, in confirmation, that a rifle fired from the left shoulder will deviate towards the *left*. The Enfield practitioners, on the contrary, always found that the ball deviated towards the right, and this deviation in some rifles is corrected by arrang-

ing the breech sight, so that it moves towards the left as it is elevated to increase the range.

Lieutenant Simons, of the Bengal Artillery, in his "Treatise on Fire Arms, London, 1857," acknowledges that in his experiments he observed that the deviation was in the direction of the revolution. He gives an explanation similar to that given by Lieutenant Gibbon in the "Artillerist's Manual." The axis of the elongated ball remains in its flight nearly parallel to itself, and is not, therefore, always tangent to the trajectory described. Hence, when the axis of the ball makes an angle with the tangent to the trajectory, if the ball is revolving from right to left, the portion of the ball on the right side meets with a greater resistance than that on the left, as a part of its rotary motion on that side coincides with its motion of progression. But this excess of resistance on the right side would obviously cause the ball to deviate towards the left, in obedience to the general law, that a body left free to obey the forces acting upon it will move in the path of least resistance. And this is exactly opposite to the direction in which experiment proves that it does deviate. Now, to explain why it will deviate towards the right, with the excess of resistance on the right, Lieutenant Simons says, by reason of this, the *point* of the bullet will become slightly tipped towards the right, and then the bullet will be drifted in that way! He does not presume to offer an explanation why it is that the point of the bullet will be tipped in the direction in which experiment proves that the drift takes place. There is no force which can give this *fortunate tip* to the bullet-point, and hence his explanation is wholly unsatisfactory.

Lieutenant Gibbon, if the writer remembers correctly, attempts to turn the point in the proper direction by asserting that this excess of resistance acts only on the rear part

of the ball, about the centre of gravity, and throws that to the *left*, leaving the point turned towards the right. This simple assertion, or supposition, has no reason to be admitted, but the contrary, and therefore cannot be received as a philosophical explanation.

Some French writer asserts that the "drift" is due to the different densities of the strata of air in which the ball (not horizontal) is revolving; that owing to the different densities the rear part of the ball is removed farther from the normal trajectory towards the left than the upper part, having a greater resistance acting on it, and thus the ball is turned with its point slightly towards the right, and hence drifts as observed.

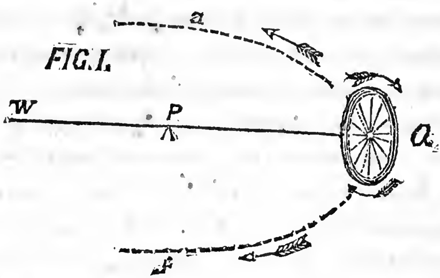
This theory of the different densities of the strata of air through which the projectile moves is unsatisfatory, inasmuch as the ball is at no time perpendicular to the horizon, and the extreme depth of the strata would not exceed 10 or 12 inches. And, again, owing to the velocity of the ball, and the violent commotion produced in the air around it, and the condensation of the resisting medium in front of the ball, we are brought to the conclusion, that if there is any difference in the densities of the strata resisting its motion, it is almost inappreciable, and is wholly inadequate to produce the deviation observed.

As all the theories mentioned to explain the "drift" of the rifle ball are altogether inadequate and wholly unsatisfactory, we propose an explanation entirely different. This theory of "drift" at least has the merit of being actually tested, and if it is correct, it suggests an easy method of preventing "drift," and of thus rendering the rifle free from all inaccuracy.

The forces acting on an elongated rifle ball in motion, are similar to those acting on the gyroscope when put in motion, and its aberration or *precession* is exactly similar to that of the gyroscope. It is well known that if the wheel (q) of

the gyroscope is made to revolve rapidly in the direction indicated by the arrows, and the axis *p q*, perpendicular to the wheel *q*, is rested on a point of support at *p*, the excess of weight being on the side *q*, the wheel *q* will gradually move

FIG. I.



towards *a*. But if the excess of weight is on the side *w*, thereby leaving a resultant to draw *w* downwards, and the wheel *q* still is made to revolve towards the right, indicated by the arrows, then *q* will move towards *b*, or the whole will revolve around *p*, in the direction in which the wheel *q* revolves. If the weights at *w* and *q* are equal, then, by revolving *q*, there will be no motion around *p*. These are the *facts* of the action of the gyroscope. It is not designed here to attempt to offer the received explanation; suffice it to say, that the forces which produce this apparently anomalous motion are similar to those which produce the retrogradation in the line of nodes of the moon's orbit, and the precession of the equinoxes; and we propose to make the "drift" of the rifle ball subject to the same general law.

In the elongated rifle ball, with the soft metal attached to its base, the centre of gravity is not midway between the axis of the cone and the base, but is nearer the base of the ball. If the elongated ball is placed horizontally in any supporting

medium, it will be found that the centre of buoyancy, as the resultant of all the buoyant forces, will be between the centre of gravity and the apex of the cone. If the ball is placed horizontally in mercury, the base of it will sink until the resultant of the buoyant forces passes through the centre of gravity. If it is placed horizontally in air, the same thing will take place as the ball begins to fall, though the buoyant forces will be less in the ratio of the density of mercury to that of air. Suppose the ball represented by Fig. 2, is revolv-

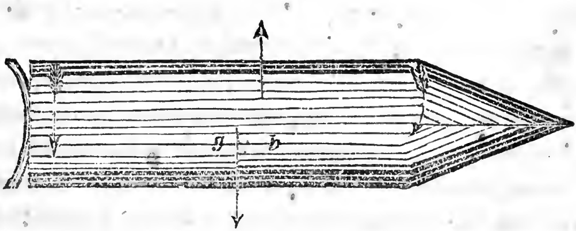


FIG. 2.

ing towards the right, as indicated by the arrows, *g*, the centre of gravity, (the ball being leaded at the base) and *b*, the centre of buoyancy, it is obvious by the influence of gravity and the buoyant force of the air there will be a *tendency* for the base to descend and the apex to ascend, or a tendency to revolve around a point situated between *g* and *b*. Now confining the attention to the front of the ball revolving towards the right, with a tendency to ascend, it will be seen that it is acted on by forces similar to the gyroscope, (fig. 1) when the excess of weight is at *w;* hence it will move in a similar manner, or the point of the ball will move towards the right. The

base of the ball is revolving towards the right, with a *tendency* to descend, hence it is acted on by forces similar to the gyroscope, (fig. 1) with the excess of weight at the wheel q, and the base therefore will recede to the *left*. By this analysis we get a *couple* which tends to revolve the ball horizontally, with its point to the right. It is true these forces would be very slight, but still sufficient to produce the "drift" that is observed. Were the ball revolving towards the left, a similar analysis would show that the tendency was to turn the point to the left, and thus cause the drift in that direction.

Of what practical use is this theory of the cause of "drift?" We propose by it to correct the only inaccuracy to which the rifle ball is liable. It was mentioned, in speaking of the gyroscope, (fig. 1) that when the weights at p and w were equal, or when the instrument was exactly supported at its centre of gravity, there was no tendency to move either to right or left, no matter in what direction the wheel q revolved; consequently, if our theory is correct, it will follow, by throwing the centre of gravity forward, so as to make it coincide in a vertical line with the centre of buoyancy, there will be no tendency whatever in the rifle ball to deviate to the right or left. If the centre of gravity is thrown (by extracting metal from the base of the ball) nearer to the apex than the centre of buoyancy, the deviation of the ball will be in a direction contrary to what is now observed. To sum up, we affirm that if a rifle ball is so constructed that it will float horizontally in mercury, it will have no "drift." If opportunity occurs it is designed to test the correctness of our theory by actual experiment.

In speaking of gunpowder, we endeavored to state clearly the reason why it is necessary to have the powder for guns of large calibre of large grains. The inertia of rest has to be overcome. This cannot be done *instantaneously*; an interval

of time is required. Hence with large grains a longer interval of time is required to consume the whole charge, and the projectile is made to move when only a *portion* of the charge is converted into gas, and thus it receives its great initial velocity without danger to the gun. Suppose the ball is not sent home, but is allowed to rest in the bore, say one foot from the charge, the result will be, that the first gas generated will not act to move the ball, but to condense powerfully the air in the vacant space. The whole or a great part of the charge will be consumed, and gas of powerful tension be brought to act on the ball in a state of rest; this, by its elasticity, will rebound, and meeting with other gas of powerful tension, will produce a powerful strain on the interior of the bore of sufficient power, it may be, to burst it. That the gas acts in this way to burst the gun, is inferred from some experiments in which the ball was designedly left some inches from the charge. In these experiments it was found that when the tension was not sufficient to burst the gun, the barrel expanded in the form of a ring, not exactly *at* the ball, but a few inches nearer the breech. Guns have been known to burst by the muzzle getting accidentally filled with clay or even snow. Fulminates that are *instantaneously* converted into gas will burst a gun without the assistance of a ball. The inertia of the air which fills the bore, resists so powerfully the rapid movement of the gas, that its whole force is exerted against the material of the gun, which cannot withstand its effects.

From these considerations we cannot insist too strongly upon *the great importance of sending the ball home against the charge.* Several unfortunate accidents have already happened in our service from the bursting of large guns; we fear some of them from neglect of the important consideration to which we now allude. This is especially important in rifle guns, as a very

slight flaw in the bore catching the soft metal of the cup, may check the ball before it is home, and thus deceive the rammer. This may happen especially in the percussion rifle shell, which is sent home by the rammer with great caution and not rapidly. The unfortunate results attending some of the accidents, teach us that too great caution cannot be used. The bursting of some of the rifle guns was no doubt caused by the balls becoming *wedged fast* in the bore. The ordnance department has attempted to avoid this by a new arrangement of the soft metal, which it is believed will be successful.

It is by no means to be inferred that if a cannon once projects, without bursting, a ball *not at home*, it will do so a second and a third time. The shock received at first may be just sufficient to prepare the gun for bursting under similar conditions on the second or third fire.

We may remark just here, that it is now an established fact, that the devices cast upon the exterior of old guns seriously injured their powers to resist the explosion of the charge. The tendency of the cast metal is to crystallize perpendicular to the cooling surfaces. Hence, our guns are made now as smooth and regular as possible on the exterior. Steel is better for a rifle gun than iron or bronze, inasmuch as its bore will admit of a higher finish, and hence the friction of the ball will be much diminished.

RANGE OF THE ARMSTRONG GUN.

The Armstrong gun, 4 inch bore, charge $3\frac{1}{2}$ pounds, weight of ball 29 pounds, has the following ranges, as determined by experiments at West Point, 1860:

Elevation.	Range.	Time.
	Yards.	
5°	2099	7.5″
7°	2894	9.1″
10°	3700	11.6″
12°	4196	14.2″
15°	4776	17.1″
20°	6070	21.4″
25°	6580	25.0″
30°	7555	31.0″
35°	9000	

DRIFT OF THE RIFLE.

The mean drift of 40 shots fired from a rifle musket, at a distance of 1,150 yards, was 18 feet to the right.

The following important table gives the drift of the French rifle cannon with a helix of 4.37 feet:

Range—in yards, ...	218	328	437	546	656	765	874	984	1093	1312	1421
Drift—in feet and inches, . .	.5″	1′.1″	1.′9″	2′.0″	4′.9″	7′.6″	11′.6″	16′.1″	21′.0″	38′.4″	56′.6″

This shows, that for a range of 1,421 yards, the drift was as much as 50 feet to the right. A deviation which it is important for the gunner to provide against in firing rifle cannon at long ranges.

V.

RESISTANCE OF THE AIR.

Were it possible to project a ball from a cannon in *vacuo*, it would be acted upon by two forces: the impulsive force of the propellant gas, and the constant acting force of gravity. The spaces through which gravity would draw it would vary as the squares of the times, or as the squares of the spaces through which it would pass, acted on solely by the impulsive force. This mathematical consideration, from the known relation existing between the abscissa and ordinate of the parabola, clearly demonstrates that the trajectory of the ball, acted on solely by these forces, would be a parabola. But the supposition is a case that is impossible to exist. Instead of having only two forces, the impulsive force and the force of gravity, there acts on every ball projected from a gun a third force of powerful influence, which modifies, in a remarkable manner, its trajectory, and causes it to be no longer a parabola, but a curve, which somewhat assimilates to that, in the first portion of the path described. This third force is the resistance which the air offers to the passage of the projectile through it.

In the early calculations, this force was entirely neglected. All calculations were made on the supposition that the trajectory was a parabola. The discrepancy existing between theory and practice induced Sir Isaac Newton to give it his attention. He inferred the law that the resistance was proportional to the square of the velocity, and calculated the ranges for that basis. The science of gunnery thereby re-

ceived considerable advance, but still it was far from perfection. Mr. Robins undertook the most elaborate experiments on this subject that were ever performed before or since. They extended through many years. His experiments established beyond a doubt, that the resistance of the air for very great velocities, increased in a far greater ratio than that of the square of the velocity. The following considerations will lead us to the same inference. Air rushes into vacuum with a velocity of from 1,200 to 1,300 feet per second. Now, when a ball is moving with a velocity greater than this, say 1,600 feet per second, there is a vacuum formed behind it; hence, the pressure of the air, 15 pounds to the square inch, is removed from the rear of the ball, but exists in front. Again, as the ball moves forward more rapidly than the air can move away, the atmosphere must be powerfully condensed in front of tho ball, and by its increased density and elasticity add powerfully to the resistance.

Consequently, a ball moving with very great velocity, equal to the initial velocity of a rifle ball, meets with a wall of condensed air in front, and is entirely relieved of pressure in the rear. Hence, when the ball moves with a velocity greater than 1,300 feet, there is another element of resistance brought into action which rapidly augments the resistance above that attained from the law of the duplicate ratio of the velocity.

It is the generally received law, that for small velocities the resistance offered by any fluid is as the square of the velocity. But it remained for Robins to determine the cause of the difference between practice and the theory of Sir Isaac Newton, and to show at what particular stage of the velocity the ordinary assumed law of resistance underwent its modification. Robins determined by his experiments that the resistance of the air on the surface of a bullet three-fourths of an inch in diameter,

with a velocity of 1,650 feet, amounted to as much as a weight of 10 pounds. An iron ball 24 pounds weight, with a velocity of 1,650 feet, has a resistance of 540 pounds. He supposed that the change in the resistance of the air was very suddenly increased when the projectile attained the velocity of air passing into vacuum, and that, however great the initial velocity of the ball might be, it would, within the first 500 yards of range, be reduced, on account of the powerful resistance, to a velocity of 1,200 feet per second.

Robins gives the following rules for calculating the resistance of air to projectiles:

1. If the velocity of the projectile is less than 1,100 feet per second, the resistance varies as the square of the velocity, and its mean quantity is a half ounce avoirdupois on a 12 pound shot moving with a velocity of 25 or 26 feet per second.

2. If the velocity is greater than 1,100, then the resistance is three times as great as it would appear to be by the first rule.

Prof. Robinson gives the following rule to find the velocity with which a ball must move to meet with a resistance from the air equal to its own weight:

RULE.—Multiply the diameter of the ball in *inches* by 300. The product will be the space in *yards*, through which the ball must fall in vacuum to acquire the velocity which will cause it moving through air to meet with a resistance equal to its weight.

This rule is determined from a mathematical formula. Calling this space s, we have for velocity acquired in falling through this space $v = 2\sqrt{16\,s} = 8\sqrt{s}$. The resistance corresponding to $8\sqrt{s} = w$, its weight. Hence,

$$(8\sqrt{s})^2 \ : \ v'^2 \ :: \ W \ : \ x,$$

when x is the resistance corresponding to v'. For velocities exceeding 1,200, $3x$ will be the true value of the resistance.

An application of the above principles gives the following amounts:

A 6 pounder ball (3.58 inches diameter), with a velocity of 1,650 feet, meets with a resistance equal 39 times its weight, or 234 pounds.

A 12 pounder ball (4.51 inches diameter), with a velocity of 1,650 feet, meets with a resistance equal 30 times it own weight, or 360 pounds.

A 24 pounder ball (5.68 inches diameter), with a velocity of 1,650 feet, meets with a resistance equal 26 times its own weight, or 624 pounds.

A 32 pounder ball (6.25 inches diameter), with a velocity of 1,650 feet, meets with a resistance equal 23 times its own weight, or 736 pounds.

A 42 pounder ball (6.84 inches diameter), with a velocity of 1,650 feet, meets with a resistance equal 21 times its weight, or 882 pounds.

A 64 pounder ball (7.88 inches diameter), with a velocity of 1,650 feet, meets with a resistance equal 18 times its weight, or 1,152 pounds.

An 130 pounder ball (9.88 inches diameter) with a velocity of 1,650 feet, meets with a resistance equal 15 times it weight, or 1,950 pounds.

These are the resistances on spherical balls, and are enormous. In view of the great amount of this resistance, it has occurred to the writer that it is possible, by giving the ball a proper shape, to convert a portion of this resisting force into a force to produce rotation. It has not yet been done. Still he has such confidence in his theoretical examination of the subject as to feel satisfied that the next improvement in gun-

nery will be to *rifle the ball instead of the gun.* He has proposed for trial to the Ordnance Department two methods, one of which depends on the principle of reaction, or inequality of pressure of the air passing in an orifice in front of the ball and escaping by small tangential orifices near the circumference. Experiment alone must be the final test of the merit of these suggestions.

Upon the supposition that there is no resisting medium, we find by calculation that a ball projected at an angle of 45°, with a velocity of 1,600 feet, would have the extreme range of twenty-one miles! Whereas in practice we know it ranges but little over three miles.

Wilcox, in his "Rifle and Rifle Practice," gives the forms of nearly one hundred different shaped balls, formed for the purpose of diminishing to the least degree the resistance of the air, and of producing the greatest accuracy. On this subject Major Mordecai says, "the *paraboloid* fulfills in the highest degree every requisite, as here all the deviated elements produced backward form focal lines, and unite at the focus. This form also secures the greatest divergence of the deflected air currents, and consequently the least opposition from the resistance of the air."

VI.

FUZES.

Shells, when first used, were fired from mortars, and lighted by the hand just before the charge was exploded. It was afterwards discovered that the flame of the escaping gas was sufficient to produce ignition. They are called time fuzes, and concussion or percussion, according as they explode by the fuze being ignited by the flame, or by coming in contact with a resisting object. The old wooden fuze plugs, with mealed powder in paper for a time fuze, are still used, only instead of having different lengths of fuze to burn different times, the same length is made to burn 5, 10 or 15 seconds, by giving to the mealed powder different degrees of pressure.

The Bormann fuze, now so well known, and used in all our field pieces, possesses the great advantage of having the pressure applied horizontally to the mealed powder, and thereby causing equal lengths of the fuze to burn in equal times. Some of the first issued from the Ordnance Department were not well screwed in the shell, and consequently many burst very near the muzzle, if not in the gun, no matter for how many seconds they were cut. The writer conceived that this premature explosion was in a measure due to the flame passing between the thread of the screw and the shell, and had the fuzes, of all the shells in the battery to which he was attached, screwed in as tight as possible with the fuze wrench, and then

had the space around the exterior rim of the fuze very closely glazed with a mixture of white lead and litharge. When this glazing hardened he had the satisfaction, on subsequent trials, of witnessing very few premature explosions. If the metal is cut away so as to expose a surface as large as the fourth of a half dime, explosion will take place. Of course the fuze end of the shell is placed towards the muzzle; if towards the charge, the violent explosion of the powder would drive the fuze into the shell and cause it to burst in the gun.

The Splingard concussion fuze consists of a hollow cone of gypsum, with its base to the interior of the shell, and its exterior firmly packed around with mealed powder. This mealed powder burns during the flight, and when the shell strikes, the cone is unsupported, and is broken by the shock, when the flame is communicated to the interior and produces explosion. It is said to have acted well on trial.

The English Navy percussion fuze, invented by Captain Moorsom, has three brass hammers suspended by wire in cavities in the shell. Opposite the ends of these hammers is placed fulminating powder communicating with the shell. The shock of the shell striking is supposed to break the hammers, or one of them, from the fastenings, and cause the explosion by impact against the fulminate.

The French Navy percussion shell, invented by Captain Bilbette, has a breaker of iron attached to a steel screw, and to the breaker is attached a chord passing through chlorate of potash and sulphuret of antimony. By the shock the steel screw, to explode the shell, must break, when the cord, drawn through the substances mentioned, causes explosion.

The writer has submitted a model of a percussion fuze, which has met the approval of the Ordnance Department. It is adapted both to the round and elongated shell, and is regarded

as superior to that adopted by the English and French Navy, inasmuch as it is easier of construction, of less cost, and will more certainly explode. For hand-grenades it seems perfectly adapted.

The rifle shell fuze explodes by the momentum of a small mass, upon which is placed a percussion cap, striking, when the shell is suddenly checked, against the cover of the fuze. It is said to act well when the shell strikes point foremost.

Sir Howard Douglas asserts that "a percussion shell cannot be lodged in the wood if the percussion apparatus performs its function," and Commander Dahlgreen remarks that it does not appear that this has been satisfactorily demonstrated, and considers it an "open question." Colonel Jacob, in his experiments, demonstrated that it was no longer an "open question," but, "that the *comparatively slow ignition of the gunpowder allows the shell to penetrate deeply before bursting.*" He regarded his "percussion rifle shells as the most formidable missile ever invented by man." They consist of a copper tube filled with powder thrust into a deep opening cast in the fore end of the ball. The end of the tube is tipped with percussion powder, and the tube held in the ball with resinous cement. With these shell, fired from his rifle, Colonel Jacob exploded caissons at a distance of 1,200 and even 1,800 yards! He regards it possible for two good marksmen, armed with his rifle and these shell, to annihilate a battery of field artillery in a short time, at a distance of 1,000 or 1,200 yards; and his own successful experiments seemed to render his assertion by no means improbable.

VII.

SIGHTING GUNS—HOW TO MAKE SIGHTS.

The problem of sighting a gun, at present, (thanks to the theoretical investigations and the thousand experiments) is exceedingly simple. Everything has been done for the gunner before he goes into the field. The initial velocity, depending on the weight of the ball and the charge of powder, being fixed, there remain two other variable elements to determine the trajectory of a solid shot, the range and the angle of elevation, one of them being given the other can be determined. In the case of a shell, we find three variable elements, range, elevation and time, two of which must be known to determine the other. But the gunner is not required to solve any mathematical equations. Tables, carefully prepared from theory and experiment, giving the elevation, range and time of flight for each calibre, are published, and it is only required of the gunner to make an intelligent use of them. These tables will be found in the last section of these notes.

The breech of the cannon is larger than the muzzle, and if a line be drawn from the breech to the muzzle, it will not be parallel to the axis of the bore, but makes an angle with it. Hence the line of metal is not parallel to the axis of the bore.

The difference betweeen the radii of the muzzle and the breech is called the "*dispart.*" Every gun should have a muzzle sight, which should be made exactly equal to the *dis-*

part. The *dispart* is found thus: measure with a graduated tape carefully the circumference of the muzzle and of the breech. The circumference divided by 3.1416 will give the diameter. Half the difference between the diameters thus calculated will be the dispart.

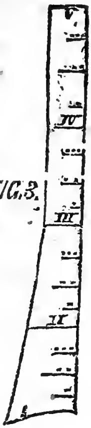
The muzzle sight equal to the *dispart*, would enable the gunner readily to make the axis of the bore horizontal, by sighting directly at the object, when in the same horizontal plane, and thus secure a rolling fire. But our guns are not usually made with muzzle sights, and to bring the axis horizontal, it is necessary to *depress* the muzzle, so that the line of sight, along the line of metal, produced, shall pierce the horizontal plane about 100 yards in advance of the piece. The angle between the line of metal and the axis of the bore is usually one degree, and for angles of elevation greater than one degree, the muzzle sight gives no peculiar advantages.

The lateral direction of the gun, in a field piece, is best given by seizing the trail handspike. Standing in that position, the sight can be better corrected. It has occurred to the writer that, possibly, considerable accuracy and facility of aim might be given to a field piece, by having a *lateral screw*, to work by the hand, fixed near the elevating screw, so as to give the gun motion to the right or left of about one degree. This might be done by attaching the cheeks to a wrought iron plate, fastened to the trail stock by a belt.

If it happens that the guns are not provided with breech sights, tangent scales or pendulum hauses, as did occur in the writer's case, the gunner can construct for himself a tangent scale which will answer all his purposes. Measure accurately the length of the gun from the muzzle sight, or highest point of the muzzle, to the base ring; multiply this length in inches by the natural tangent of one degree (.01746.) The product will be the

length of the tangent corresponding to one degree for that gun. Now have a piece of mahogany or walnut prepared of shape of figure 3, with one straight edge, and curvature at bottom to fit the base ring of the gun, and lay off on this the distances corresponding to a tangent of one degree. If the dispart is equal to tangent of one degree, the first space laid off must be marked 2°, the next 3°, &c. Subdivide these spaces into equal parts, and we have the tangents of a quarter of a degree. Now prepare a small square slide about one inch long and a half inch wide, to hold between the thumb and finger of the left hand. If the distance requires an elevation of 3°, place the slide on the tangent scale at the line marked III, hold the scale vertical, or rather perpendicular to the bore, which is done by a broad bore fitting firmly on the base ring, and sight over the top of the slide and muzzle at the object; taking care that the straight edge of the tangent scale coincides with the mark on the base ring denoting the highest point of the breech. In the absence of a slide, the thumb of the left hand may be used to sight over, or notches may be cut at the marks. This form of sight may be used, or a circular breech sight of wood serves an excellent purpose. Immediately opposite (in the tangent scale, or underneath in the breech sight), the marks of degrees and quarter degrees there should be placed, in conspicuous figures, the distance corresponding to that elevation for solid shot; also, in another column, marked "spherical case," there should be put the distance and time of flight corresponding thereto, and in the same manner for shell.

FIG. 3.



The gunner thus constantly has his table before him. He judges of the distance by the eye, and immediately opposite that distance his tangent scale tells him what elevation to use; and if he desires to use spherical case or shell, he has recorded just by the distance, the time to cut the fuze by. With this arrangement, the gunner *guesses* at nothing but the distance of the object. The time and elevation corresponding to each distance are recorded on his scale ready to hand, and it is only concerning the distance about which he is called upon to form a judgment. Hence the great importance of having the eye trained to judge accurately of distances.

INSTRUMENTS TO DETERMINE DISTANCES.

Two classes of instruments have been proposed for determining distances, one measures the visual angle and the other superposes images. The French *stadia* is simply a graduated rule, held vertically at a fixed distance from the eye, say two feet. To use it, the top of the stadia is brought tangent to the ray of light from the head of the man observed, and the thumb nail or a slide moved up until it is tangent to the ray of light from the feet. And the mark indicated on the stadia will be the distance required. We suppose that the average height is 5 feet 10 inches, and graduate the stadia by the proportion of similar triangles, thus, 2 feet : distance on stadia : : 600 yards : 5 feet 10 inches. This proportion gives about one-thirteenth of an inch for the graduation. So the graduation for other distances can be determined. This stadia may be graduated for cavalry, as well as infantry.

"Corporal Malphet's" instrument depends on the same principle. It is composed of a cylindrical metallic tube, hav-

ing a hole at one end to apply the eye. A second cylinder of smaller diameter is placed within the first, opened towards the eye, and closed at the other end by a circle in which is cut a narrow transversal slit. The inner cylinder is fastened to the exterior by an index working in a longitudinal slat. When the instrument is applied to the eye, the inner cylinder is moved until the two edges of the transversal slit become tangent to the object at its extremities. Then the apparent height corresponding to the distance of the object is found marked by the index against the graduations of the longitudinal slat.

But instruments cannot be relied on, especially in the excitement of action. The eye must be trained by practice to judge correctly of distances. It should be a part of the daily drill in a field battery for all the commissioned and non-commissioned officers to practice the eye in judging distances. To do this a soldier should be placed at a distance of 100, 200, 300, 400, 500, &c. yards up to 1,000 or more. At each hundred yards all should be called on to observe what part of the uniform is visible and what indistinct. Each should carefully record in his note-book opposite every hundred yards what part of the uniform or person is distinctly visible at that distance. These notes will constitute his standard of comparison, and will be different for eyes of different powers. Cavalry should be noticed as well as infantry. When this has been done frequently and each is familiar with his own standard, a soldier should be placed at an unknown distance, and each required to note down the amount in his judgment. Then the distance should be measured, and the same thing tried for other distances. Astonishing accuracy is said to be attained in this way by the French engineers. And the confidence and skill acquired by an officer with this training indi-

cates clearly that it is the duty of each to apply himself to the drill in this respect.

The tables of elevation and ranges given in the Appendix are the result of thousands of experiments made with the powder used in the old United States service. The powder used now by ourselves is probably not so strong, as our own experiments, carefully made, showed that one-fourth of a degree must be added to the elevation to secure the range opposite in the tables.

VIII.

CLASSES OF PROJECTILES—CLASSIFICATION OF FIRES—WHEN EACH SHOULD BE USED.

There are five different classes of projectiles used, solid shot, shell, spherical case, grape and canister; and the fires may be reduced to four kinds, direct, plunging, rolling and ricochet. A *direct* fire is when the object is struck directly by the projectile before it comes in contact with any other object. A *plunging* fire is when the object is struck by the projectile in the descending branch of the trajectory. A *rolling* fire is when the axis of the piece is made horizontal, and the projectile makes several ricochets before meeting the object. A *ricochet* fire is when the ball, fired at a low range of elevation, strikes the ground or water in front of the object and rebounds. There are three things necessary to be known before we can determine what projectile and what kind of fire to use: "1st, the distance of the enemy; 2d, the conformation of the ground; and 3d, the formation of the enemy."

As a general rule, solid shot are used only against troops in masses; shell and spherical case against scattered troops, but not against troops in motion; canister used only when the enemy is not more than 400 yards distant.

When a charge is being made on the battery, canister should be used as rapidly as possible. After the distance is diminished to 400 yards, and when very near the battery, two

cases of canister, fired at once from a single charge, may repulse the enemy and save the guns. Grape shot are fired from large guns under circumstances similar to those in which canister are fired from fixed pieces.

For a fire against troops in masses a *ricochet* or rolling fire is always to be preferred, if the ground is level and hard, and thereby favorable.

When a shell explodes, the splinters are acted upon by two forces, the remaining force of shell moving in its trajectory, which acts only in one direction, and the force of the explosive charge in the shell, which acts in every direction. The fragments will move in the direction of the resultant of these two forces. Some will move forward with a velocity due to the sum of these two forces; others in an oblique direction; others, laterally; and some, if the force of explosion is greater than that of progression, will have a retrograde movement.

A shell is designed to produce its effect mainly by the force of explosion, and not by the force of progression. Hence the endeavor should be to explode it *amongst* the troops of the enemy, and not in *front* of them, unless it be the object to produce a moral effect alone; then the shell should be made to explode in front, and it is all important to observe this. It is better always for the shell to explode too soon, instead of too late, as, though the physical effect may be lost, the moral is secured. And it is a generally received rule among military writers, in comparing those forces which serve to retard the progress of the enemy, that the moral is to the physical as *three to one.*

Spherical case constitute the most formidable projectile in the hands of an artillerist. A spherical case for a 24 pounder howitzer contains 175 musket bullets. These are compressed in a small space, enclosed in a case of iron, and thus projected as

a solid ball for a distance of 1,000 or 1,500 yards, meeting with the least possible resistance from the air. By the explosion of the charge within, these bullets are expanded over a considerable area, and have an effect as destructive as that of a company of infantry immediately in front of the enemy.

The charge of powder within this projectile is very small, only sufficient to break the case and well expand the bullets. The effect is due to the velocity of progression entirely; hence a spherical case should always be made to explode 50 or 75 yards in front of the enemy, and at from 20 to 50 feet elevation, so as to allow the cone of expansion of the bullets to cover the largest possible area.

The rolling or ricochet fire should always be used when the character of the ground will admit of it, as it not only increases the dangerous space, but has a moral effect in addition to the physical. If the troops are in line and not in bodies, a ricochet fire, striking 15 feet in front, will pass completely over them. If the battery is above the object, a plunging fire alone can be used; and if a fortification is to be destroyed, the direct fire must be used, taking care with a flanking piece to endeavor to enfilade the terre-plein of the enemy's works.

When the ground is rough and hilly, and the enemy are not in close masses, shell and case shot must always be used in preference to solid shot.

Too much importance cannot be given to the first fires of a battery. If fired badly, with too great elevation, the enemy is encouraged to advance by the shell bursting in his rear. If fired well, he may be deterred by a few shots. At the battle of Manassas an instance occurred in which a brigade of the enemy was driven back by *four* well directed case shot from one of our 6 pounder batteries.

It is said that all young artillerists fire too rapidly, and

thereby throw away much of their ammunition. The rule is, *fire slowly and cautiously*, and observe well the effect of the shot. Benton says once or twice a minute is as often as a field piece can be fired and *aimed well*, and that eleven or twelve times an hour is as often as heavy garrison guns can be fired with success. It is said to have rarely happened that a field battery, well served, has used the ammunition of all its chests in any one pitched battle; and it is somewhere stated that fifty rounds to a piece is as much as was used in Mexico in any engagement.

When any of the following conditions are fulfilled, Benton says shells should be employed in preference to solid shot:

1. When the enemy is stationary.
2. When the ground is much broken.
3. When the troops are posted in woods.
4. From one mountain to another.
5. When the enemy is posted on higher ground.
6. When in a road leading through a rolling country.
7. For incendiary purposes.
8. In pursuit.
9. Whenever it is necessary to produce a moral rather than a physical effect.

When shell are designed for incendiary purposes, some of the powder of the charge should be removed, and pieces of port-fire, half an inch long, inserted in its stead.

It should be observed that you cannot make a ricochet fire with a rifle cannon. The rotation of the ball acting on the surface, diverts it immediately from its normal trajectory; and it often happens, for a similar reason, that a spherical ball, from a smooth bore, is diverted from its direct course by a ricochet on water.

IX.

MISCELLANEOUS MEMORANDA.

CARE OF HORSES.

As the whole efficiency of a field battery depends in a great degree upon the condition of the horses, too great care of them cannot be taken. At regular hours of the day the feeding and grooming should be done in the presence of *all the sergeants and at least one commissioned officer.* The drivers should not be allowed to cease grooming until the drum taps, which should be at least half an hour after beginning. Each sergeant should see that the horses of his teams are all fed and well groomed, as without this close scrutiny they will deteriorate.

It would be well, also, to select some one man of most experience with horses, and appoint him supervisor of stables. It should be his business to make a daily report to the Captain of the general health of the horses, and to use the proper means to restore any that are diseased.

TO GUARD AGAINST THE ENEMY'S FIRE.

In the field, as soon as it is discovered that the enemy has obtained your range, the pieces should be moved laterally or forward, from 40 to 50 yards, and the fire rapidly resumed.

If sharp-shooters are observed in the neighboring woods they must be driven out with shell.

If the guns are mounted in a fort *en barbette*, and the cannoneers are annoyed by sharp-shooters, they should be protected by sand bags, thus forming on the parapet an embrasure.

In going into battery on the field, advantage should be taken of any rise in the ground. If the carriages are placed just behind the crest of a hill, with the guns pointing over it, great protection will be given the cannoneers, as all ricochet shots of the enemy will rebound entirely over the piece. This will occur even with a small hillock two feet high.

If the gun is in a fort it is better to serve it with five men, and possibly it may be better to use this number in the field, holding the others in reserve; as thereby fewer men are exposed. In this drill, with five men besides the gunner, Nos. 2 and 5 interchange in carrying the load, No. 3 performs the duties of Nos. 3 and 4, save the gunner acts as vents-man and No. 4 stands at the limber and delivers ammunition.

PENETRATION OF SHOT.

An 80 pound rifle shot has been known to pass through 7 feet of masonry at a distance of 1,032 yards.

At 200 yards	a rifle	bullet	penetrates	11	inches	of	pine board.
At 600	"	"	"	"	$6\frac{1}{3}$	"	"	"
At 1,000	"	"	"	"	$3\frac{1}{2}$	"	"	"

"A rope mantlet, $3\frac{1}{2}$ inches thick, as used by the Russians, will resist small arm projectiles at all distances."

Colonel Jacob mentions an experiment in which a ball from his rifle was fired through 20 inches of deal boards and buried itself a whole length in a block of hard wood.

In Dahlgreen's experiments, shot from a 32 pounder, at a distance of 1,000 yards, penetrated a mass of seasoned white-

oak the depth of 25 inches; shot from a 64 pounder, the depth of 37 inches.

PENETRATION IN IRON.

The late engagement at Hampton Roads between the two iron-clad vessels, the Virginia and Monitor, demonstrated that a succession of thick iron plates offers a better resistance to shot, than a solid mass of equal thickness. It is said that "while the turret of the Monitor, composed of eight layers, each an inch thick, was only indented $2\frac{1}{8}$ inches by a shot striking square and flat upon it, one of the solid bars or plates, nine inches thick and 12 inches deep, forming a part of the pilot house, was completely broken in two by a similar shot and opened $\frac{5}{8}$ of an inch on the back side."

Various experiments were made in England to test the resistance of iron-clad vessels to the Armstrong and Whitworth projectiles, and to 68 pound shot. The result may be stated to be that $4\frac{1}{2}$ inch iron plates, *supported behind*, are proof against shells, hot shot and cast iron shot, 68 pounders; that they have been penetrated by *wrought iron* 8 inch shot at 200 yards, and by the Whitworth projectile, a wrought iron bolt 3 inches in diameter, at the distance of 400 yards. Vessels clad with iron plates $4\frac{1}{2}$ inches thick, were considered safe against ordinary projectiles at a distance of 200 yards. With this view the French Emperor has built an iron-clad ship of war, "Le Gloire," carrying 38 rifled 50 pounders, and England has built a rival to "Le Gloire," in the Warrior.

The *rotating cupola* of the "Monitor" is an invention of Captain Cowper Coles, R. N. It, we learn, is clad with plates 8 or 9 inches thick.

The day of wooden war vessels is now numbered among the

things of the past; wrought iron in future will be the great means of defence. At present the art of attack by water, with iron-clad steamers, is superior to the art of defence. The relation between water attack and land defence has changed, the inferior has become the superior, and wrought iron plates have caused it. But the art of defence can resume its old relation of superiority to that of attack, in one way—by *increasing the calibre of the guns.* We want more 15 and 20 inch guns to *smash* the iron sides of the steamers that bid defiance to the guns that now guard our forts. We venture to assert that our present 32 pounders, 42 pounders, and even 68 pounders will have to be cast into 15 and even 20 inch guns, before our seacoast fortifications can be said to be secure.

POWER OF LEADEN BALL TO PENETRATE IRON.

We are not aware that any experiments have been made on the powers of lead to penetrate iron. Theory would be against it; but Mr. Greener, of London, mentions a curious experiment that he made: A leaden ball punched a hole through a half-inch boiler plate, when an iron ball, under the same circumstances, rebounded without any effect.

X.

TABLES OF RANGES AND ELEVATIONS.

The following tables are taken from the experiments of Dahlgreen, as recorded in the "Shells and Shell Guns:"

RANGES OF SHOT.

32 *Pounder of* 27 *Cwt.*

BORE OF GUN SEVEN FEET ABOVE WATER.

Charge.	Elevation.	Range. 1st Graze.
Lbs.	°	Yards.
4	1	545
	2	800
	3	1047
	4	1278
	5	1469
	6	1637

32 *Pounder of* 32 *Cwt.*

SEVEN AND A HALF FEET ABOVE WATER.

Charge.	Elevation.	1st Graze.
Lbs.	°	Yards.
$4\frac{1}{2}$	1	581
	2	857
	3	1140
	4	1398
	5	1598

32 *Pounder of* 42 *Cwt.*

GUN EIGHT AND ONE-THIRD FEET ABOVE WATER.

Charge.	Elevation.	1st Graze.
Lbs.	°	Yards.
5	1	616
	2	913
	3	1194
	4	1420
	5	1651

32 *Pounder of* 57 *Cwt.*

GUN NINE FEET ABOVE WATER.

Charge.	Elevation.	1st Graze.
Lbs.	°	Yards.
9	1	770
	2	1154
	3	1449
	4	1708
	5	1932
	6	2144
	10	2731

RANGES OF SHELLS.

8 *Inch of* 55 *Cwt.*

GUN SEVEN AND A HALF FEET ABOVE WATER.

Charge.	Elevation.	1st Graze.
Lbs.	°	Yards.
7	1	579
	2	869
	3	1148
	4	1413
	5	1657
	6	1866
	8	2315
	10	2600

8 Inch of 63 Cwt.

NINE FEET ABOVE WATER.

Charge.	Elevation.	1st Graze.
Lbs.	°	Yards.
9	1	662
	2	966
	3	1264
	4	1540
	5	1769

RANGES OF MOUNTAIN HOWITZERS.

The following tables are taken from the "Ordnance Manual:"

Charge.	Projectile.	Elevation.	Range.	Time.
Lbs.		° ′	Yards.	″
0.5	Shell,	0	170	
		1	300	
		2	392	
		2 30	500	2
		3	637	
		4	785	3
		5	1005	
0.5	Sph. case,	0	150	
		2 30	450	2
		3	500	
		4	700	2.7
		4 30	800	3
0.5	Canister,	4 to 5°	250	

RANGES OF FIELD GUNS AND HOWITZERS.

The range of a shot or shell in this table is the first graze of a ball on horizontal ground, the piece being mounted on its appropriate field carriage.

The range of a spherical case shot is the distance at which the shot bursts near the ground in the time given; thus showing the elevation and length of fuze required for certain distances.

KIND OF ORDNANCE.	Powder.	Ball.	Elevation.	Range.	REMARKS.
	Lbs.		° ′	Yards.	
6 PDR. FIELD GUN,	1.25	Shot	0	318	
		"	1	674	
		"	2	867	
		"	3	1138	
		"	4	1256	
		"	5	1523	
	1.	Sp. case shot	2	650	Time flight, 2 sec
			2 30	840	" " 3 "
		"	3	1050	" " 4 "
12 PDR. FIELD GUN,	2.5	Shot	0	347	
		"	1	662	
		"	1 30	785	
		"	2	909	
		"	3	1269	
		"	4	1455	
		"	5	1663	
	1.5	Sp. case	1	670	Time, 2 seconds.
		"	1 45	950	" 3 "
		"	2 30	1250	" 4 "

RANGES OF FIELD GUNS AND HOWITZERS—*Continued.*

KIND OF ORDNANCE.	Powder.	Ball.	Elevation.	Range.	REMARKS.
	Lbs.		° ′	Yards.	
12 PDR. FIELD HOWITZER.	1.	Shell	0	195	
		"	1	539	
		"	2	640	
		"	3	847	
		"	4	975	
		"	5	1072	
	0.75	Sp. case	2 15	485	Time, 2 seconds.
		"	3 15	715	" 3 "
		"	3 45	1050	" 4 "
24 PDR. FIELD HOWITZER.	2.	Shell	0	295	
		"	1	516	
		"	2	793	
		"	3	976	
		"	4	1272	
		"	5	1322	
	1.75	Sp. case	2	600	Time, 2 seconds.
		"	3	800	" 3 "
		"	5 30	1050	" 4 "
	2.	"	3 30	880	" 3 "
32 PDR. FIELD HOWITZER.	2.5	Shell	0	290	
		"	1	531	
		"	2	779	
		"	3	1029	
		"	4	1203	
		"	5	1504	
	2.5	Sp. case	3	800	Time, 2.75 sec'ds.

RANGES OF HEAVY ORDNANCE.

The *range* of a gun or howitzer in this table is the first graze of the ball on the horizontal plane on which the carriage stands.

KIND OF ORDNANCE.	Powder.	Ball.	Elevation.	Range.	REMARKS.
	Lbs.		° ′	Yards.	
18 PDR. SIEGE AND GARRISON GUN. On barbette carriage.	4.5	Shot	1	641	
		"	2	950	
		"	3	1256	
		"	4	1450	
		"	5	1592	
24 PDR. SIEGE AND GARRISON GUN. On siege carriage.	6.	Shot	0	412	
		"	1	842	
		"	1 30	953	
		"	2	1147	
		"	3	1417	
		"	4	1666	
		"	5	1901	
	8.	"	1	883	
		"	2	1170	
		"	3	1454	
		"	4	1639	
		"	5	1834	
32 PDR. SEA-COAST GUN. On barbette carriage.	6.	Shot	1 45	900	
	8.	"	1	713	
		"	1 30	800	
		"	1 35	900	
		"	2	1100	
		"	3	1433	
		"	4	1684	
		"	5	1922	
	10.67	"	1	780	
		"	2	1155	
		"	3	1517	

RANGES OF HEAVY ORDNANCE—*Continued.*

Kind of Ordnance.	Powder.	Ball.	Elevation.	Range.	Remarks.
	Lbs.		° ′	Yards.	
42 Pdr. Sea-Coast Gun. On barbette carriage.	10.5	Shot	1	775	
		"	2	1010	
		"	3	1300	
		"	4	1600	
		"	5	1955	
	14.	"	1	770	
		"	2	1128	
		"	3	1380	
		"	4	1687	
		"	5	1915	
8 Inch Seige Howitzer. On siege carriage.	4.	Shell 45 lbs.	0	251	
		"	1	435	
		"	2	618	
		"	3	720	
		"	4	992	
		"	5	1241	
		"	12 30	2280	
8 Inch Sea-Coast Howitzer. On barbette carriage.	4.	Shell 45 lbs.	1	405	
		"	2	652	
		"	3	875	
		"	4	1110	
		"	5	1300	
	6.	"	1	572	
		"	2	828	
		"	3	947	
		"	4	1168	
		"	5	1463	
	8.	"	1	646	
		"	2	909	
		"	3	1190	
		"	4	1532	
		"	5	1800	
10 Inch Sea-Coast Howitzer. On barbette carriage.	12.	Shell 90 lbs.	1	580	
		"	2	891	Time flight, 3. sec.
		"	3	1185	" " 4. "
		"	3 30	1300	
		"	4	1426	" " 5.25 "
		"	5	1650	" " 6. "

RANGES OF HEAVY ORDNANCE—*Continued.*

Kind of Ordnance.	Powder.	Ball.	Elevation.	Range.	Remarks.
	Lbs.	Shot	° ′	Yards.	
8 Inch Columbiad. On barbette carriage.	10.	65 lbs.	1	932	Axis of gun 16 feet above the water.
		"	2	1116	
		"	3	1402	
		"	4	1608	
		"	5	1847	
		"	6	2010	
		"	8	2397	Shot ceased to ricochet on water.
		"	10	2834	
		"	15	3583	
		"	20	4322	
		"	25	4875	
		"	27	4481	
	15.	"	27 30	4812	
		Shell			
	10.	50 lbs.	1	919	
		"	2	1209	
		"	3	1409	
		"	4	1697	
		"	5	1813	
		"	6	1985	
		"	8	2203	
		"	10	2657	
		"	15	3556	
		"	20	3716	
		"	25	4387	
		"	27	4171	
	15.	"	27 30	4468	
		Shot			
10 Inch Columbiad. On barbette carriage	18.	128 lbs.	0	394	Axis of gun 16 feet above the water.
		"	1	752	
		"	2	1002	
		"	3	1230	
		"	4	1570	
		"	5	1814	
		"	6	2037	Shot ceased to ricochet on water.
		"	8	2519	
		"	10	2777	
		"	15	3525	
		"	20	4020	
		"	25	4304	
		"	30	4761	
		"	35	5433	
	20.	"	39 15	5654	

RANGES OF HEAVY ORDNANCE—*Continued.*

KIND OF ORDNANCE.	Powder.	Ball.	Elevation.	Range.	REMARKS.
	Lbs.	Shell	°	Yards.	
10 INCH COLUMBIAD—Continued.	12.	100 lbs.	1	800	
		"	2	1012	
		"	3	1184	
		"	4	1443	
		"	5	1604	
	18.	"	0	448	
		"	1	747	
		"	2	1100	
		"	3	1239	
		"	4	1611	
		"	5	1865	
		"	6	2209	
		"	8	2489	
		"	10	2848	
		"	15	3200	
		"	20	3885	
		"	25	4150	
		"	30	4651	
		"	35	4828	Time flight, 35 sec.
		Shell			
12 INCH COLUMBIAD.	20.	172 lbs.	10	2770	Time flight, 11 sec.
		"	15	3731	" " 16 "
		"	22	4280	" " 20 "
		"	25	4718	" " 26 "
		"	30	5004	
		"	35	5339	" " 32 "
		"	37	5266	" " 31 "
		"	39	5064	
	25.	"	10	2881	" " 11.5 "
		"	15	3542	" " 15 "
		"	30	5102	
		"	35	5409	" " 32 "
		"	37	5373	" " 32 "
		"	39	5506	" " 36 "
		Shell	35	5644	
		180 lbs.	39	5615	
	28.	"	35	5671	
		"	39	5761	$3\frac{1}{3}$ miles. Time, 36 seconds.
		Shell			
13 INCH SEA-COAST MORTAR.	20.	200 lbs.	45	4325	

RANGES OF HEAVY ORDNANCE—*Continued.*

Kind of Ordnance.	Powder.	Ball.	Elevation.	Range.	Remarks.
	Lbs.	Shell	°	Yards.	
12 Inch Sea-Coast Mortar.	20.	200 lbs.	45	4625	Experimental.
		Shell			
10 Inch Sea-Coast Mortar.	10.	98 lbs.	45	4250	Time, flight 36 sec.
		Shell			
10 In. Siege Mortar.	1.	90 lbs.	45	300	Time flight, 6.5 s.
	1.5	"	45	700	" " 12 sec.
	2.	"	45	1000	" " 14 "
	2.5	"	45	1300	" " 16 "
	3.	"	45	1600	" " 18 "
	3.5	"	45	1900	" " 19 "
	4.	"	45	2100	" " 21 "
	Lbs. oz.	Shell			
8 Inch Siege Mortar. (From Griffith's Artillerist's Manual.)	0 10¾	46 lbs.	45	500	Time flight, 10 sec.
	13¾	"	45	600	" " 11 "
	1	"	45	750	" " 12¼ "
	1 2	"	45	900	" " 13 "
	1 3½	"	45	1000	" " 13½ "
	1 4¾	"	45	1100	" " 14 "
	1 6	"	45	1200	" " 14½ "
	Oz.	Shell			
24 Pounder Coehorn Mortar.	0.5	17 lbs.	45	25	
	1.	"	45	68	
	1.5	"	45	104	
	1.75	"	45	143	
	2.	"	45	165	
	2.75	"	45	260	
	4.	"	45	422	
	6.	"	45	900	
	8.	"	45	1200	

PENETRATION OF SHOT IN MASONRY.

FROM EXPERIMENTS MADE AT METZ IN 1834, AT A DISTANCE OF 219 YARDS

Calibre.	Charge in weight of Shot.	Penetration in inches.
36*	$\frac{1}{3}$	24
24	$\frac{1}{2}$	22
"	$\frac{1}{3}$	21
"	$\frac{1}{4}$	20
"	$\frac{1}{8}$	14
12	$\frac{1}{3}$	16
"	$\frac{1}{4}$	14
"	$\frac{1}{6}$	13
"	$\frac{1}{8}$	11

PENETRATION IN OAK WOOD,

AT A DISTANCE OF 219 YARDS.

Calibre.	Charge in weight of ball.	Penetration in inches.
36	$\frac{1}{3}$	58
24	$\frac{1}{2}$	54
"	$\frac{1}{3}$	51
"	$\frac{1}{4}$	48
"	$\frac{1}{6}$	42
12	$\frac{1}{3}$	38
"	$\frac{1}{4}$	36
"	$\frac{1}{6}$	31
"	$\frac{1}{8}$	27

* The 36 pounder corresponds nearly with our 42 pounder.

PENETRATION IN OAK WOOD,

AT A DISTANCE OF 219 YARDS.

Calibre.	Charge.	Penetration in inches.
Howitzer.	Lbs.	
8 inch.	4.4	22
"	3.3	18
"	2.2	12
12 pdr.	2.2	22
"	1.1	13

PENETRATION IN COMPACT EARTH, (HALF SAND AND HALF CLAY,)

AT A DISTANCE OF 219 YARDS.

Calibre.	Charge.	Penetration in inches.
36	⅓	97
24	½	91
"	¼	77
12	⅓	54
"	¼	52
"	⅛	44
Howitzer.		
8 inch.	4.4 lbs.	41
"	2.2 "	29
24 pdr.	2.2 "	36
"	1.1 "	27

The penetrations in other kinds of earth are found by multiplying their numbers: for sand mixed with gravel, by the co-efficient 0.63
For wet potter's clay, by the co-efficient . . 1.44
For light earth settled, by 1.50

In general, sand, sandy earth mixed with gravel or small stones, chalk and turf, resist shot better than the productive earth or clay, or earth that retains water.

INITIAL VELOCITIES OF CANNON BALLS.

Calibre.	Projectiles.	Charge.	Initial Velocity.
		Lbs.	Feet.
6 pounder,	Shot	1.25	1439
"	"	2.	1741
12 pounder,	"	2.5	1486
"	"	4.	1826
12 pdr. howitzer,	Shell	1.25	1178
24 pounder,	Shot	4.	1440
"	"	6.	1680
"	"	8.	1870
32 pounder,	"	5.33	1430
"	"	8.	1640
"	Canister	4.	1172
"	Grape	4.	1133

TERMINAL VELOCITIES OF CANNON BALLS.

The velocity of a projectile diminishes from the commencement of its flight to a point a little beyond the summit of the trajectory: it then increases to a certain limit. The following table gives the final velocities:

	Shot.					Shell.				Musket ball.
Calibre, . .	42	24	18	12	6	13 in.	10 in.	8 in.	24 pdr.	
Final velocity of descent in feet, . . .	485	455	425	410	360	585	505	445	375	213